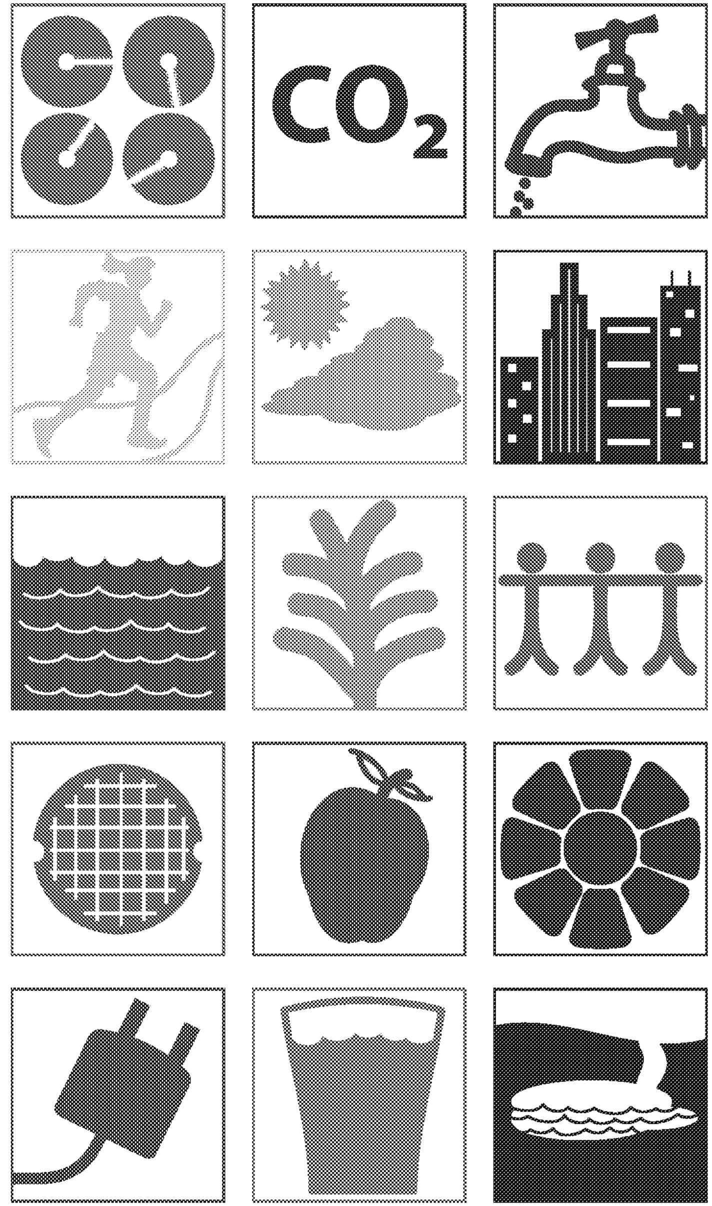
# The Value of Green Infrastructure

## A Guide to Recognizing Its Economic, Environmental and Social Benefits

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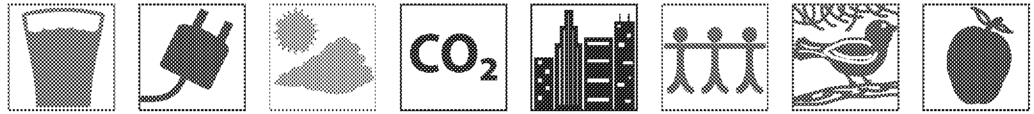


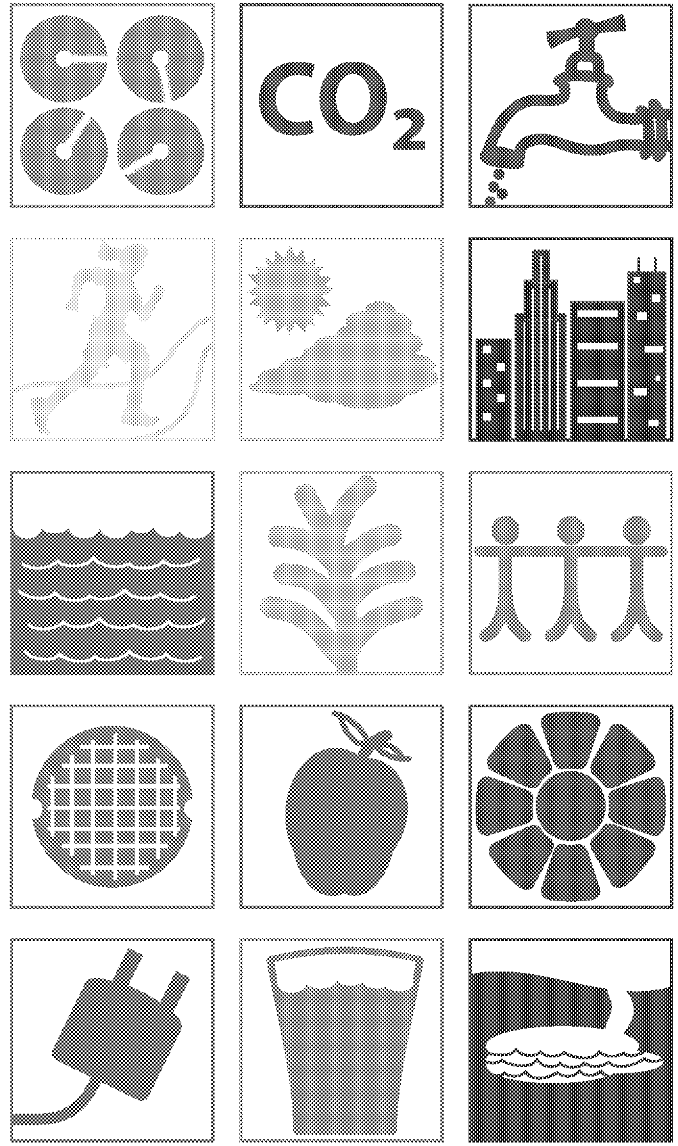
# Acknowledgements

This guide owes thanks to a variety of people and organizations that were instrumental in its development. First among those is The Center for Neighborhood Technology's (CNT) project team, led by Joe Grant and Danielle Gallet, along with Stephanie Morse, Steve Wise, Cece Yu, Kathrine Nichols, Kalle Butler Waterhouse and Marie Donahue.

Initial funding for research into the type of benefits Green Infrastructure produces came from the U.S. Environmental Protection Agency's (EPA) Office of Water and Watersheds, with project management through Tetra Tech, following a January 2008 EPA workshop on research issues. Funding and review by American Rivers, specifically William Hewes and Betsy Otto, was essential to the completion of this handbook and its sections on valuation of particular benefit types. American Rivers' support for the project was made possible by the Kresge Foundation. The Peggy Notebaert Nature Museum donated space for a 2010 workshop to review initial concepts and the path to benefit valuation.

The following advisors shared their time and expertise in a variety of different ways including reviewing initial concepts and guidebook drafts, contributing to particular practice and benefit sections, and presenting at the 2010 workshop. Those include Dr. John Braden of the University of Illinois, Chris Kloss of the Low Impact Development Center, Ed MacMullen of EcoNorthwest, Dr. Franco Montalto of Drexel University, Dan Nees of Forest Trends, David Nowak of the U.S. Forest Service, Steven Peck of Green Roofs for Healthy Cities, Dr. Sabina Shaikh of the University of Chicago, Robert Goo of the U.S. EPA, Mike Alonso of Casey Trees and Jen McGraw of CNT.

This work also extends initial research in support of CNT's Green Values Calculator® (greenvalues.cnt.org), which identified additional values related to green infrastructure practices. Under funding from the Joyce Foundation, CNT's Bill Eyring, Julia Kennedy and Daniel Hollander documented a range of benefits that were the starting points for the research of this guide.



# Introduction

## What Is Green Infrastructure & Why Does It Matter?

Green infrastructure (GI) is a network of decentralized stormwater management practices, such as green roofs, trees, rain gardens and permeable pavement, that can capture and infiltrate rain where it falls, thus reducing stormwater runoff and improving the health of surrounding waterways. While there are different scales of green infrastructure, such as large swaths of land set aside for preservation, this guide focuses on GI's benefits within the urban context.

The ability of these practices to deliver multiple ecological, economic and social benefits or services has made green infrastructure an increasingly popular strategy in recent years. (See Case Study section.) In addition to reducing polluted stormwater runoff, GI practices can also positively impact energy consumption, air quality, carbon reduction and sequestration, property prices, recreation and other elements of community health and vitality that have monetary or other social value. Moreover, green infrastructure practices provide flexibility to communities faced with the need to adapt infrastructure to a changing climate.

## Why This Guide?

Although valuation of green infrastructure's monetary benefits has advanced considerably in recent years, it is still a developing field. The EPA publication *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices* (2007) documented the comparative construction costs of green infrastructure practices in residential construction but did not explore performance benefits. While numerous published studies address either the benefits coming from one type of practice, such as energy implications of green roofs, or the collective impacts of a single practice, such as urban forestry's impact on water, energy, and other elements, such studies do not achieve a cumulative assessment of multiple benefits.

Green infrastructure's value as a municipal or private investment depends in part on its effects beyond water management and thus upon a community's ability to model and measure these additional values. Short of conducting an intensive study and calculation of actions in a specific community, municipalities have generally lacked the tools to determine green infrastructure's multiple benefits. As such, defining or measuring the extent of green infrastructure's multiple benefits has remained a challenge. While a number of cities have begun to explore GI within their own municipal infrastructure programs, no general method for estimating or documenting such benefits has yet emerged.

Due to these gaps in information and methodology, decision-making regarding stormwater infrastructure investments has generally lacked recognition of the monetary benefits that GI provides communities. With limited ability to quantify GI's benefits, municipalities have often favored single-purpose grey infrastructure projects. However, any cost-benefit analysis comparing grey infrastructure with green infrastructure would be incomplete without factoring in the multiple benefits green infrastructure can provide.

## Purpose of the Guide

This guide distills key considerations involved in assessing the economic merits of green infrastructure practices. It examines the steps necessary to calculate a variety of performance benefits gained by implementing GI strategies and then, where possible, demonstrates simplified illustrative examples that estimate the magnitude and value of these benefits.

In clarifying how to assign value to potential green infrastructure benefits, this guide can assist decision-makers in evaluating options for water management. A more clear view of GI's values will help communities decide where, when and to what extent green infrastructure practices should become part of future planning, development and redevelopment.

**The guide aims to:**

- **Inform decision-makers and planners about the multiple benefits green infrastructure delivers to communities.**
- **Guide communities in valuing the benefits of potential green infrastructure investments.**

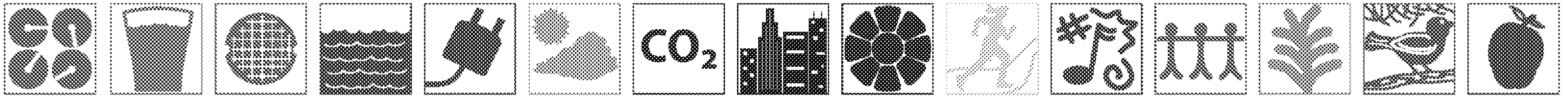
# Green Infrastructure Benefits and Practices

This section, while not providing a comprehensive list of green infrastructure practices, describes the five GI practices that are the focus of this guide and examines the breadth of benefits this type of infrastructure can offer. The following matrix is an illustrative summary of how these practices can produce different combinations of benefits. Please note that these benefits accrue at varying scales according to local factors such as climate and population.

| | Reduces Stormwater Runoff | | | | | | | | | | | Improves Community Livability | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Benefit | Reduces Water Treatment Needs | Improves Water Quality | Reduces Grey Infrastructure Needs | Reduces Flooding | Increases Available Water Supply | Increases Groundwater Recharge | Reduces Salt Use | Reduces Energy Use | Improves Air Quality | Reduces Atmospheric $CO_2$ | Reduces Urban Heat Island | Improves Aesthetics | Increases Recreational Opportunity | Reduces Noise Pollution | Improves Community Cohesion | Urban Agriculture | Improves Habitat | Cultivates Public Education Opportunities |
| Practice | | | | | | | | | | $CO_2$ | | | | | | | | |
| Green Roofs | Yes | Yes | Yes | Yes | No | No | No | Yes | Yes | Yes | Yes | Yes | Maybe | Yes | Maybe | Maybe | Yes | Yes |
| Tree Planting | Yes | Yes | Yes | Yes | No | Maybe | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Maybe | Yes | Yes |
| Bioretention & Infiltration | Yes | Yes | Yes | Yes | Maybe | Maybe | No | No | Yes | Yes | Yes | Yes | Yes | Maybe | Maybe | No | Yes | Yes |
| Permeable Pavement | Yes | Yes | Yes | Yes | No | Maybe | Yes | Maybe | Yes | Yes | Yes | No | No | Yes | No | No | No | Yes |
| Water Harvesting | Yes | Yes | Yes | Yes | Yes | Maybe | No | Maybe | Maybe | Maybe | No | No | No | No | No | No | No | Yes |

Yes  Maybe  No

# Green Roofs




A green roof is a rooftop that is partially or completely covered with a growing medium and vegetation planted over a waterproofing membrane. It may also include additional layers such as a root barrier and drainage and irrigation systems. Green roofs are separated into several categories based on the depth of their growing media. **Extensive** green roofs have a growing media depth of two to six inches. **Intensive** green roofs feature growing media depth greater than six inches (GRHC).

As green, or vegetated, roof systems become more prevalent in the United States, the benefits they can provide to a wide range of private and public entities become more apparent. These benefits are outlined below.

**Reduces Stormwater Runoff:**

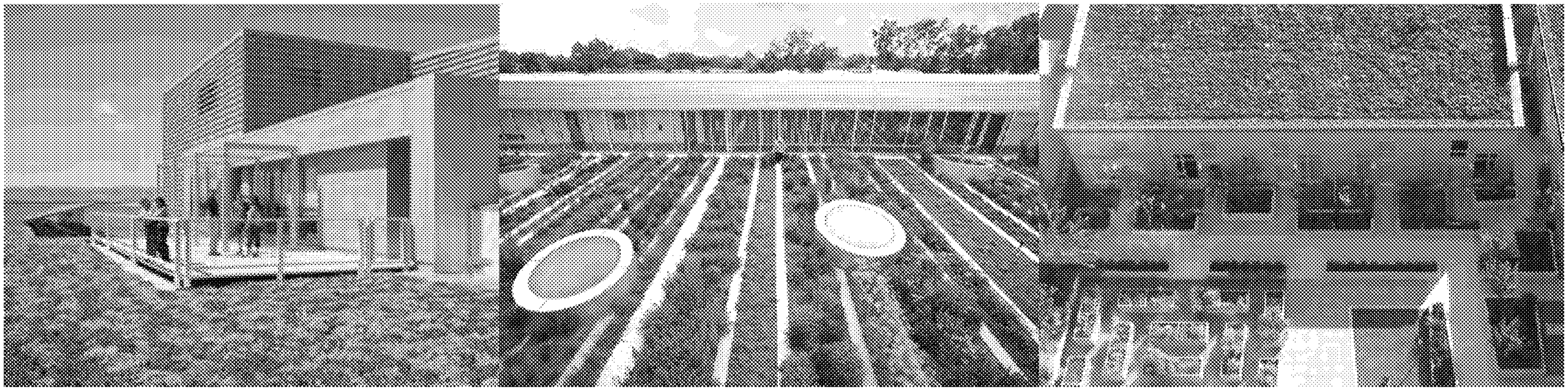
- Green roofs can store significant amounts of water in their growing media. This water is eventually evaporated from the soil or transpired by the plants on the roof, thus reducing the runoff entering sewer systems and waterways, which can help alleviate the risk of combined sewer overflows (CSO).

**Reduces Energy Use:**

- Additional insulation provided by the growing media of a green roof can reduce a building's energy consumption by providing superior insulation compared to conventional roofing materials.
- The presence of plants and growing media reduces the amount of solar radiation reaching the roof's surface, decreasing roof surface temperatures and heat influx during warm-weather months.
- Evaporative cooling from water retained in the growing media reduces roof surface temperatures.

**Improves Air Quality:**

- Locally, the vegetation planted on green roofs takes up air pollutants and intercepts particulate matter.
- The cooling effect of vegetation lessens smog formation by



slowing the reaction rate of nitrogen oxides and volatile organic compounds.

- By reducing energy use, green roofs lessen the air pollution caused by electricity generation.

**Reduces Atmospheric $CO_2$:**

- Green roof vegetation directly sequesters carbon.
- By reducing energy use and the urban heat island effect, green roofs lower carbon dioxide emissions from regional electricity generation.

**Reduces Urban Heat Island:**

- The local evaporative cooling provided by green roofs can reduce elevated temperatures present in urban areas as a result of heat-absorbing surfaces such as streets and conventional roofs.

**Improves Community Livability:**

- Green roofs improve the local aesthetics of a community.
- Soil and vegetation help reduce sound transmission, thus reducing local noise pollution levels.
- Green roofs can increase recreational opportunities by providing outdoor areas for people to use and enjoy. They also have the potential to foster improved community interactions that help build social capital.
- Green roofs may also provide opportunities for urban agriculture.

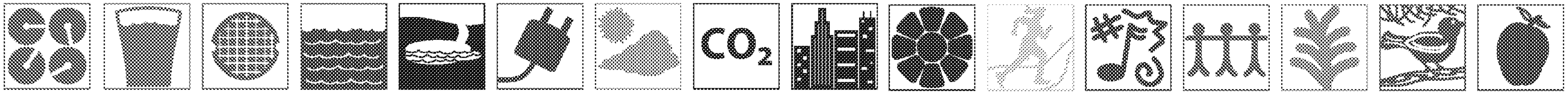
**Improves Habitat:**

- Increased vegetation helps to support biodiversity and provides valuable habitat for a variety of flora and fauna.

**Cultivates Public Education Opportunities:**

- Managing future economic and environmental constraints will require full community participation and partnership. Green infrastructure provides an opportunity to develop community awareness and understanding around the importance of sustainable water resource management.
- Green roofs increase community interest in green infrastructure through their aesthetic appeal, which provides a great opportunity for public education.

# Tree Planting




Planting trees provides many services which have ecological, economic and social implications. Whether measured on a tree-by-tree basis or on a larger scale such as an urban forest, tree planting has a multitude of benefits.

**Reduces Stormwater Runoff:**

- Trees intercept rainfall and help increase infiltration and the ability of soil to store water.
- Tree canopies diminish the impact of raindrops on barren surfaces.
- Transpiration through leaves minimizes soil moisture, which reduces runoff.

**Increases Groundwater Recharge:**

- Trees can contribute to local aquifer recharge and to the improvement of watershed system health, from both quantity and quality standpoints.

**Reduces Energy Use:**

- When properly placed, trees provide shade, which can help cool the air and reduce the amount of heat reaching and being absorbed by buildings. In warm weather, this can reduce the energy needed to cool buildings.
- Trees reduce wind speeds. Wind speed, especially in areas with cold winters, can have a significant impact on the energy needed for heating.
- Trees release water into the atmosphere, resulting in cooler air temperatures and reduced building energy consumption.

**Improves Air Quality:**

- Trees absorb air pollutants (e.g. $NO_2$, $SO_2$, and $O_3$) and intercept particulate matter (PM10).
- Trees reduce energy consumption, which improves air quality and reduces the amount of greenhouse gases, including $N_2O$ and $CH_4$.

**Reduces Atmospheric $CO_2$:**

- Through direct sequestration, trees reduce atmospheric carbon dioxide levels.
- Tree planting reduces energy consumption, which in turn reduces $CO_2$ levels.



**Reduces Urban Heat Island:**

- The various cooling functions of trees help to reduce the urban heat island effect, thereby reducing heat stress-related illnesses and fatalities.

**Improves Community Livability:**

- Trees provide beauty and privacy, which improve community aesthetics.
- Planting trees increases recreational opportunities for communities by improving pathways, creating places to gather and providing shade during warm weather.
- Trees provide a sense of place and well-being, which can strengthen community cohesion.
- Trees help to reduce sound transmission, reducing local noise pollution levels.
- Tree planting may provide opportunities for urban foraging and food production.

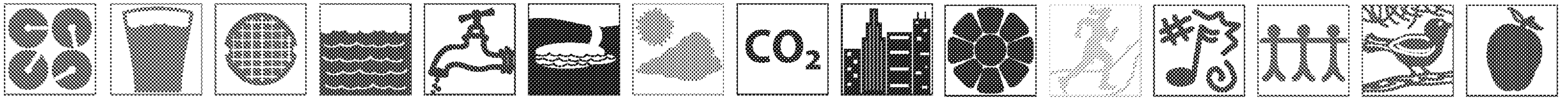
**Improves Habitat**

- Planting trees increases wildlife habitat, especially when plant species native to the region are used.

**Cultivates Public Education Opportunities:**

- Managing future economic and environmental constraints will require full community participation and partnership. Green infrastructure provides an opportunity to develop community awareness and understanding around the importance of sustainable water resource management.
- Community tree planting provides a valuable educational opportunity for residents to become more aware of the benefits of green infrastructure.

# Bioretention and Infiltration Practices



Bioretention and infiltration practices come in a variety of types and scales, including rain gardens, bioswales and wetlands. Rain gardens are dug at the bottom of a slope in order to collect water from a roof downspout or adjacent impervious surface. They perform best if planted with long-rooted plants like native grasses. Bioswales are typically installed within or next to paved areas like parking lots or along roads and sidewalks. They allow water to pool for a period of time and then drain, and are designed to allow for overflow into the sewer system. Bioswales effectively trap silt and other pollutants that are normally carried in the runoff from impermeable surfaces. While the multitude of benefits provided by wetlands has been well documented elsewhere, this guide only addresses smaller scale practices.

**Reduces Stormwater Runoff:**

- These practices store and infiltrate stormwater, which mitigates flood impacts and prevents the stormwater from polluting local waterways.

**Increases Available Water Supply:**

- By reducing the amount of potable water used for outdoor irrigation, these practices may also increase available water supplies.

**Increases Groundwater Recharge:**

- Bioretention and infiltration practices have the potential to increase groundwater recharge by directing rainwater into the ground instead of pipes.

**Improves Air Quality:**

- Like other vegetated green infrastructure features, infiltration practices can improve air quality through uptake of criteria air pollutants and the deposition of particulate matter.
- By minimizing the amount of water entering treatment facilities, these practices also reduce energy use which, in turn, reduces air pollution by lowering the amount of greenhouses gases emitted.

**Reduces Atmospheric $CO_2$:**

- Bioretention and infiltration practices reduce carbon dioxide emissions through direct carbon sequestration.

- By reducing the amount of energy needed to treat runoff, as well as reductions in energy use for cooling purposes, bioretention and infiltration practices reduce atmospheric $CO_2$.

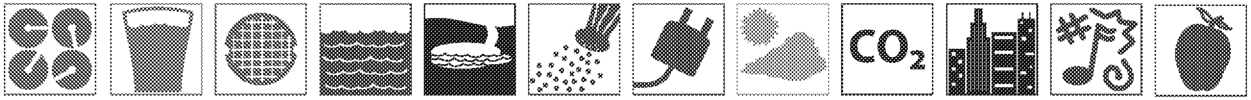
**Reduces Urban Heat Island:**
- Through evaporative cooling and reduction of surface albedo, these practices work to mitigate the urban heat island effect, reducing energy use.

**Improves Community Livability:**
- When well-maintained, bioretention and infiltration practices improve local aesthetics and enhance recreational opportunities within communities.
- There is also the potential for these practices to help reduce noise transmission through sound absorption and to improve social networks in neighborhoods.

**Improves Habitat:**
- Bio-retention and infiltration practices provide habitat and increase biodiversity.

**Cultivates Public Education Opportunities:**
- Managing future economic and environmental constraints will require full community participation and partnership. Green infrastructure provides an opportunity to develop community awareness and understanding around the importance of sustainable water resource management.
- Rain gardens and bioswales provide an opportunity for residents to contribute to the benefits of neighborhood place-making via green infrastructure.

# Permeable Pavement




Permeable pavement allows for the absorption and infiltration of rainwater and snow melt onsite. There are several different names that refer to types of permeable pavement, including pervious or porous concrete, porous asphalt and interlocking permeable pavers.

**Reduces Stormwater Runoff:**

- Permeable pavement reduces surface runoff volumes and rates by allowing stormwater to infiltrate underlying soils.
- By reducing runoff volumes and rates, permeable pavement can lower water treatment costs and reduce flooding and erosion.

**Increases Groundwater Recharge:**

- By allowing rainfall to infiltrate, permeable pavement can help increase groundwater recharge.

**Reduces Salt Use:**

- Permeable pavement has been demonstrated to substantially delay the formation of a frost layer in winter climates, which mitigates the need for salt use. By reducing the need for salt, communities are able to save money and reduce pollution in local waterways and groundwater sources.

**Reduces Energy Use:**

- The use of permeable pavements also has the potential to reduce energy use by lowering surrounding air temperatures, which in turn reduces demand on cooling systems within buildings.

**Improves Air Quality:**

- Because permeable pavement captures rainfall onsite, communities can reduce the amount of water treatment needed, in turn reducing air pollution from power plants.

- By reducing the urban heat island effect, permeable pavement decreases ground level ozone formation, which directly impacts air quality.

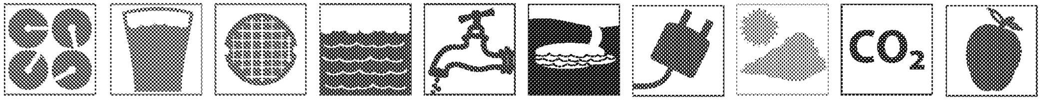
**Reduces Atmospheric $CO_2$:**
- Permeable pavement captures rainfall onsite, enabling communities to reduce the amount of water treatment needed, in turn reducing $CO_2$ emissions from power plants.
- Permeable pavement also has the potential of reducing lifecycle $CO_2$ emissions compared to asphalt and cement, which produce high lifecycle $CO_2$ emissions.

**Reduces Urban Heat Island:**
- Permeable pavement absorbs less heat than conventional pavement, which helps to reduce the surrounding air temperature and decrease the amount of energy needed for cooling.

**Improves Community Livability:**
- Some types of permeable pavement reduce local noise pollution by increasing street porosity levels.

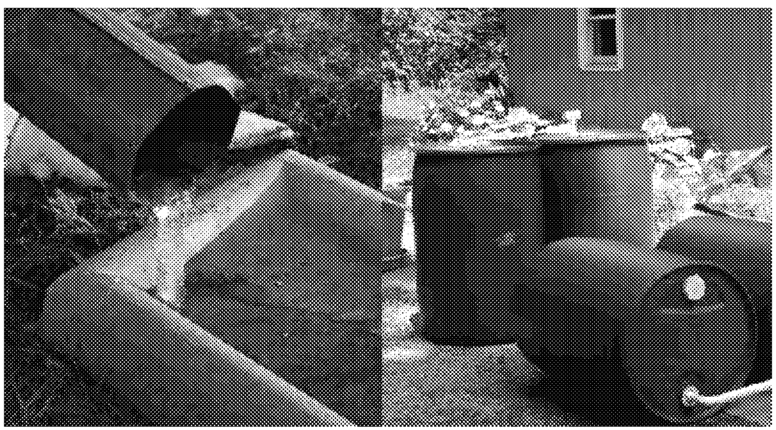
**Cultivates Public Education Opportunities:**
- Managing future economic and environmental constraints will require full community participation and partnership. Green infrastructure provides an opportunity to develop community awareness and understanding around the importance of sustainable water resource management.
- The installation of permeable pavement can provide an opportunity to further educate the public about the benefits of green infrastructure.

# Water Harvesting




Water harvesting is defined as the redirection and productive use of rainwater by capturing and storing it onsite for irrigation, toilet flushing and other potential uses. Water harvesting treats rainwater as a resource rather than as a waste stream. There are two main water harvesting practices: downspout disconnection and the use of rain barrels or cisterns.

Downspout disconnection is the process of directing roof runoff away from sewer systems and onto local property for irrigation purposes. Using rain barrels or cisterns captures rainwater, diverting it directly into these storage containers. The stored water can be used onsite for multiple purposes such as flushing toilets and irrigation. The practice of water harvesting requires that catchment areas be sized according to projected water-use needs in order to maximize the benefits of this practice.



**Reduces Stormwater Runoff:**

- Water harvesting minimizes the negative impacts of stormwater runoff by capturing rainfall where it lands and reusing it onsite.
- Onsite reuse of rainwater helps to reduce water treatment needs, which allows communities to save on costs associated with potable water conveyance, treatment and use.

**Increases Available Water Supply:**

- It is estimated that, nationwide, outdoor irrigation accounts for almost one-third of all residential water use, totaling more than 7 billion gallons per day. Given this estimate, using rainwater for irrigation purposes can substantially reduce the amount of potable water used residentially, effectively increasing supply.

**Increases Groundwater Recharge:**

- Reusing rainwater for irrigation purposes can help increase groundwater recharge.

**Reduces Energy Use:**

- Water harvesting has the ability to reduce energy usage by cutting down on potable water use, which requires energy to produce, treat and transport.